Study on Considerations of the Dry Storage Facility for Light Water Reactors from Safeguards viewpoint

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1. Introduction

In Republic of Korea (ROK), there are Pressurized Water Reactors (PWRs) 21 units and Pressurized Heavy Water Reactors (PHWRs) 3 units in operation as of 2021 [1]. Kori Unit 1 and Wolsong Unit 1 were permanently shut down and is under preparation for decommissioning [2, 3]. Spent fuel generated from Nuclear Power Plants (NPPs) has been stored at spent fuel pool. For decommissioning, the spent fuel cooled down at wet storage facilities should be transferred to another facilities (interim storage facilities). However, the storage capacity of spent fuel at the Kori site is expected to be full by 2024 [3]. For this reason, the construction and operation of dry storage facilities for PWRs spent fuel is urgent.

The stakeholders are considering installation of dry storage facilities for conventional PWRs, and has experience in construction and operation of dry storage facilities (i.e., Silos, MACSTOR/KN-400) for PHWRs at Wolsong site. Before a new nuclear facility (e.g., dry storage facilities for PWRs) is introduced, it is necessary to consider regulation standards and requirements for safeguards. Safeguards are defined as verification using nuclear material accounting, containment, surveillance and inspection to ensure that nuclear material is not diverse. According to construction experience of MACSTOR/KN-400, the stakeholders and regulation body were discussed with the International Atomic Energy Agency (IAEA) how to apply safeguards during the design phase. It was helpful in construction and operation because safeguards applied during operation were considered in the design phase.

Through MACSTOR/KN-400's case of applying safeguards, it was suggested that it is important to consider how to apply safeguards in design phase of the facility. It is necessary to develop regulatory requirement for safeguards, before dry storage facilities for PWRs is introduced. In this paper, the IAEA's Safeguards Manual Criteria (SMC) [4] and case of safeguards implementation for dry storage facilities were analyzed, and considerations were drawn to help develop the safeguards application for the facilities.

2. Status of Spent Fuel Storage

According to the Korea Hydro & Nuclear Power Co., Ltd. (KHNP)'s operational information for NPPs, Table. I shows the status of spent fuel at each site.

Table I: The storage rate of spent fuel by storage facility, 2021.04.

Site	Reactor	Unit	Storage rate (%)
Kori	PWR	6 units	82.1
Saeul	PWR	2 units	19.0
Hanbit	PWR	6 units	73.4
Hanul	PWR	6 units	85.9
Wolsong	PWR	2 units	56.3
	PHWR	4 units	95.0
	Dry storage facility (i.e., Silo, MACSTOR)		98.7

2.1 Pressurized Water Reactors

Except for Wolsong units 1, 2, 3 and 4, NPPs in ROK are PWRs. The Spent fuel generated from PWRs is temporarily stored in a spent fuel pool at each unit storage, because the construction of dry storage facilities for PWRs has not been decided. According to the Basic Plan on High-level Radioactive Waste Management, the on-site storage capacity of spent fuel pool is predicted to be saturated in the order of Kori, Hanbit (2024), Hanul (2037) and Wolsong (2038) [3]. The storage capacity was increased by applying method such as installation of high-density storage racks and transfer of spent fuel to neighboring units [2]. Therefore, installation of dry storage facilities for PWRs is urgent. A KORAD-21 (i.e., dual purpose cask for spent fuel in PWRs) is under development by the KOrea RADioactive waste agency (KORAD) in ROK [5].

2.2 Pressurized Heavy Water Reactors

The PHWRs such as the CANDU (CANada Deuterium Uranium) reactor at Wolsong site utilize natural uranium as nuclear fuel and has a short refuel cycle, and 21,000 bundles of spent fuel generated every year. Spent fuel generated from PHWRs is cooled down in spent fuel pool for 6 years and transferred to the dry storage facilities. Dry storage facilities such as 300 silos, 7 MACSTOR/KN-400 were built to increase the storage capacity of the spent fuel pool [2]. Nevertheless, it is confirmed that the storage rate of spent fuel pool is 95% and that of dry storage facilities is 98.7% as shown in Table I. Therefore, 7 additional MACSTOR/KN-400 are being construct and will be operated as of 2021.

When introducing a new nuclear facility, safeguards regulatory standards and requirements for the facility should be prepared. According to the case of facility introduction in Korea, the IAEA evaluated the applicability of safeguards based on basic design of MACSTOR/KN-400, and changed the design to apply safeguards measure such as tube for reverification and sealing. If the Korea Institute of Nuclear Nonproliferation and Control (KINAC) prepares safeguards for the facility, the safeguards required in the operation phase will be applied appropriately.

3. Safeguards

3.1 Safeguards Manual Criteria

The Safeguards Manual Criteria (SMC) of IAEA [4] specifies inspection criteria, safeguards activities and requirements for nuclear facilities. As the working-level discussion on the safeguards application plan with the IAEA is discussed based on the SMC, it is necessary to refer to the requirements for the facility.

Among the SMCs of the IAEA [4], the criteria related to the safeguards regulation of dry storage facilities for PWRs are as follows:

First, there are two items that are applied before the spent fuel is transferred to the dry storage facility.

Shipments of spent fuel from the facility are verified, following notification to the Agency. Transfers of spent fuel into containers which will be shipped to long-term storage under safeguards but will be difficult-to-access are verified in accordance with para 1(b) of SMC 14, Annex 4 and the container is placed under dual containment/surveillance (dual C/S) (see SMC 9, para 3.2(b)).

The nuclear material is verified prior to its becoming difficult-to-access by item counting, item identification and Non-Destructive Assay (NDA), using sampling plans that provide a high detection probability for gross and partial defects, and dual C/S is applied (see SMC 14, Annex 4, para 1(b)).

Second, it is an application requirement for Dual C/S system condition and remeasurement.

For added confidence and therefore to reduce the remeasurement requirements, all credible diversion paths are covered by two C/S devices which are functionally independent and are not subject to a common tampering or failure mode, e.g. two different types of seals (E-type and COBRA), seals plus surveillance, surveillance plus surveillance using equipment based on different techniques, or, in a dynamic situation, an automated material transfer monitor. dual C/S system is evaluated as Dual Conclusive positive only if both C/S devices on each credible diversion path are evaluated as Conclusive positive (see SMC 14, Annex 3, para 3.2).

When the Dual C/S system is evaluated as either Acceptable Dual C/S (i.e., Dual Conclusive positive) or Acceptable Single C/S, no remeasurement is required (see SMC 14, Annex 4, para 2).

In other words, if it is difficult to access the dry storage facility by loading the spent fuel, the dual C/S system (seals and surveillance) should be attached to the cask after verification. If the function of dual C/S system is maintained even after being transferred to a dry storage facility, remeasurement is not required.

3.2 Safeguards Implementation

Considerations for spent fuel verification, sealing, and optimal monitoring were analyzed through examples of safeguards implementation in dry storage facilities at domestic and oversea.

First, the dual-purpose cask (i.e., transport and storage cask) in Germany is verified using the ion fork device, and the spent fuel is loaded in the reactor building and transported to and stored in the on-site temporary storage facility [6]. The facility consisted of a storage area (SA), a reception area (RA), and a maintenance area (MA) as shown in Fig. 1. The surveillance camera of IAEA consists of two cameras in the storage area and one in the maintenance area.

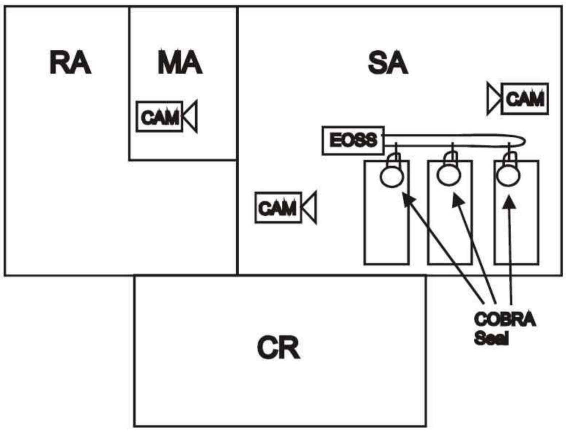

Fig. 1. On-site storage facility in Germany [6]

Before the cask is transferred to the on-site temporary storage facility, COBRA fibre optic seal and metal seal were attached to the cask to apply a dual C/S. Access to storage areas should be minimized to reduce the exposure of operator. The remote monitoring was secured, by applying Electronic Optical Sealing System (EOSS) to group of casks.

Second, a dry storage facility in ROK is defined as a difficult-to-access, and the spent fuel assembly is verified through item counting, item identification, and NDA (e.g., Neutron Detection) before entering the difficult-to-access state. The MACSTOR/KN-400 of the

PHWRs has a COBRA fibre optic seal and a metal seal applied to the designed a tube for sealing.

Finally, in the Dry Storage Canister (DSC) of the Bruce NPPs in Canada, two independent U-shaped tubes for sealing are designed in the body and the lid. COBRA fiber optic seal and metal seal were attached to the tube for sealing.

3.3 Safeguards Considerations

In Sections 3.1 and 3.2, considerations for developing safeguards for new nuclear facilities are summarized by integrating the SMC requirements and the existing safeguards approach for dry storage facilities as shown in Table II. It was confirmed that the safeguards application plan at domestic and overseas applied to the dry storage facility were the attachment of seal and surveillance camera.

Table II: Criteria for new nuclear facilities Based on the SMC and safeguards approach

Criteria	Reference
Verification for spent fuel	SMC 9, para 3.2(b)
Verification for spent fuel	SMC 14, Annex 4, para 1(b)
Attachment of Dual C/S	SMC 14, Annex 4, para 1(b)
Reverification for Dual C/S	SMC 14, Annex 3, para 3.2
Reverification for spent fuel	SMC 14, Annex 4, para 2
Attachment of surveillance system	SMC 9, para 3.2

The safeguards considerations for dual-purpose cask, which were derived by integrating the SMC and case of safeguards implementation, are as follows:

First, in accordance with SMC 9, it is necessary to verify the spent fuel in loading phase. In accordance with SMC 14, Annex 4, the spent fuel is verified by item counting, identification and NDA. In addition, a Dual C/S should be attached for sealing and surveillance. For sealing, the IAEA' seal (i.e., COBRA fibre optic seal, metal seal) is installed, and the tube for attaching the seal should be considered in the design.

Second, when the cask arrives at the dry storage facility, the seal attached to the cask is reverified. In accordance with SMC 14, Annex 3, reverification of spent fuel is not required if the function of the seal is maintained.

In accordance with SMC 9, para 3.2, the storage area should be equipped with surveillance cameras. Therefore, an independent power supply of the camera and a cable for data transmission are required.

4. Conclusions

Currently, there is experience in constructing and operating dry storage facilities for PHWRs in ROK, but the operation of dry storage facilities for PWRs has not been decided. Safeguards was considered in the design phase of MACSTOR/KN-400, and new nuclear facilities also need to prepare considerations for the application of safeguards.

Among the SMC requirements of the IAEA, the safeguards considerations for dry storage facilities such as verification for spent fuel, attachment of dual C/S and reverification were derived. In addition, essential considerations were analyzed through case of safeguards implementation for dry storage facilities at domestic and oversea that have been negotiated with the IAEA. Considerations for safeguards for PWRs dry storage facilities are summarized based on the analyzed contents.

In the future, when negotiating with the IAEA on how to apply safeguards to dry storage facilities, it is necessary to apply safeguards from KINAC. The considerations in this paper are basic research for the development of safeguards application, and it is expected that additional supplementation will be helpful in deriving safeguards application for regulations.

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